

ENAMELED WIRE HAVING MAGNETIC RELUCTANCE PROPERTIES
AND PREPARATION METHOD THEREOF, AND COIL USING THE SAME AND
PREPARATION METHOD THEREOF

5 Technical Field

The present invention relates to a magnetoresistant enameled wire, and more particularly to a magnetoresistant enameled wire, a method for manufacturing the magnetoresistant enameled wire, a magnetoresistant coil using the magnetoresistant wire, and a method for manufacturing the magnetoresistant coil, the magnetoresistant
10 enameled wire showing improved conductivity by reducing resistance of a conductor since the wire exhibits effects similar to anisotropic magnetoresistance or tunneling magnetoresistance when it is manufactured in the form of a coil, and externally exhibiting a strong magnetic flux density.

15 Background Art

Typically, used with electric appliances, communication equipments, sound equipments, etc., are coils manufactured by winding an insulated wire around a supporting tube and insulating varnish thereon so as to stick to and close fit the windings each other or manufactured by coating a self-bonding varnish on the insulated wire
20 instead of the insulating varnish and winding the wire, and then heating, applying electricity, or applying a solvent, etc., so as to be bonded the windings to each other.

However, these kinds of coils are limited to inhibit the heat generated by the resistance of the conductor while the electricity is applied thereto, thereby the temperature rise causes the waste of energy and deteriorate the exterior magnetic flux
25 density.

Korean Laid-Open Publication No. 1989-0006095 discloses low energy loss oxide magnetic material. In more detail, it discloses a method for manufacturing low

energy-loss oxide-magnetic material comprising the composite oxide of low energy loss Mn-Zn series which noticeably drops the power loss at high frequency and high electrical load for applying to the power source for a display monitor and color television set and magnetic core of transformer, particularly with the magnetic core of the transformer the a
 5 method for manufacturing the oxide magnetic material which is capable of minimizing the power loss at temperature of about 60°C~100°C. Table 1 shows the results of comparison between Comparative examples and Examples which follow.

[Table 1]

Classification	Minor Components			Initial magnetic Permeability (ui)	Power Loss (mW/cm ²)
	Al	SiO ₂	CaO		
Comparative Example 1	50	200	1000	1880	65
Example 1	0	200	1000	1750	90
Comparative Example 13	60	200	1000	1900	58
Example 4	0	200	1000	1750	90

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Also, Korean Laid-Open Publication No. 1992-013493 discloses an oxide magnetic material utilized for power sources of various electric appliances, particularly, a composite oxide magnetic material which has low power loss, high saturation magnetic flux density, and low magnetic flux density so as to be capable of miniaturizing the
 15 power supply of industrial equipments such as TV, VCR, computer, facsimile, etc., and of which main component is Fe₂O₃, ZnO and MnO. The characteristics of the oxide magnetic material are shown in Table 2 below.

[Table 2]

Classification	Additive components (wt %)			B-H Characteristic		Power loss (molecular weight/cc)	
	CaO	V ₂ O ₅	GeO ₂	Bm	Br	250°C	100°C
Example 1	0.02	0.05	0.15	5200	1700	200	140

Example 2	0.02	0.02	0.20	5250	1500	190	135°
Comparative Example 1	0.02	0.05	-	4800	2600	300	180
Comparative Example 2	0.07	0.01	0.40	4900	2600	270	170

Also, Korean Laid-Open Publication No. 1993-0001250 discloses a low power loss oxide magnetic material and a manufacturing method thereof and, in more detail, a composite oxide of Mn-Zn series for the core of the transformer utilized for a power supply of display monitor and a manufacturing method thereof.

In addition, Korean Utility Model Patent Laid-Open No. 20-0166183 discloses an electromagnetic wave-shielding wire, which is an alloy composed of ferromagnetic nickel and cobalt having high magnetic permeability. It's object is to provide the electromagnetic wave-shielding wire capable of minimizing the bad effect associated with the human body and data error and transmission energy loss of the electromagnetic media which are caused by an exterior magnetic field being effect to the electric wire.

Also, the ferromagnetic nickel and cobalt alloy shield having a thickness of $8\mu\text{m}$ to 0.4mm is a high magnetic permeability material and condenses and seals the electromagnetic wave so as to prevent the electromagnetic wave, especially the magnetic field from permeating, resulting in prevention of radiation outside.

However, as disclosed in the specification, even though the electric field can considerably be shield using the high conductivity material or ground system, it is difficult to shield the magnetic field due to the permeability of the magnetic field. The electric field is generated in a straightforward direction from the origin and can be removed or weakened by wood, building, skin of human, etc. On the other hand, the magnetic field is produced in the form of circle on the axis of the origin such that it is not easily removed or weakened by the wood, building, skin of human, etc.

The household electrical appliances use 60Hz alternating current and battery is a direct current source. The alternating current produces magnetic fields generating weak direct current, which is called induction currents and make a bad effect to the human

body. On the other hand, it is known that the direct current does not generate the induction currents.

Typically, it is known that the electric field is caused by electric voltage and the magnetic field is caused by the electric current.

5 The disclosed nickel and cobalt alloy shield having a thickness of $8\mu\text{m}$ to 0.4mm is likely to shield the magnetic field only when the current flowing on the wire is very weak because the magnetic field is not removed or weakened by any material and the high permeability nickel-cobalt alloy is easily magnetized so as to form strong magnetic field.

 Korean Patent Laid-Open No. 2000-0033283 discloses a speaker voice coil
10 manufactured in such a way of winding the coil around the support tube, fitting the windings of the coil to each other by means of adhesive tape, and doping iron oxide so as to form a magnetic layer thereon. Also, Korean Patent Laid-Open No. 2000-0033282 discloses a speaker voice coil manufactured by forming an isolation layer and fusion layer on the outer surface of coated wire and forming an iron oxide magnetic coat or
15 adding the iron oxide magnetic substance to the fusion layer. These kinds of speaker voice coils have advantages in that the voice coil is fixed to the center of the thickness of the front plate which composes of the voice coil by the iron oxide magnetic substance coated onto the coil or the wire when the voice coil is installed by coupling to the axle of the rear plate of the speaker using a separate jig. The voice coil is identically fixed to the
20 center of the thickness of the front plate since the iron oxide always creates the exterior magnetic field. Accordingly, the voice coil maintains a predetermined distance from the speaker located rear side in the magnetic levitation effect while maintaining its center, which give effects of improvement of the sound distortion, i.e. Klirrfactor, and productivity increase.

25 Generally, iron oxides can be divided into FeO , Fe_3O_4 , Fe_2O_3 and Fe_2O_3 can be classified into $\alpha\text{-Fe}_2\text{O}_3$ and $\gamma\text{-Fe}_2\text{O}_3$. Among them, Fe_3O_4 , and $\gamma\text{-Fe}_2\text{O}_3$ have spontaneous magnetization values and their coercive forces are very low. For example, Fe_3O_4 , and

$\gamma\text{-Fe}_2\text{O}_3$ have the coercive force of approximate 200 to 450 Oe and saturation magnetization values of respective 0.6 and 0.5 Tesla, and their residual magnetization values are about 80% of the saturation magnetization value. The coercive force of Fe_3O_4 and $\gamma\text{-Fe}_2\text{O}_3$ is enough for exterior magnetic field of voice coil.

5 The enameled wire is called magnetic wire in general, and is manufactured in combination with the coating, wire-drawing, and varnish manufacturing techniques.

 The varnish for an insulation coating is constantly developed so as to resist the heat of 250°C and also the coating and wire-drawing techniques are developed to the extent that the bare copper less than 0.05mm in diameter can be coated and purified.

10. However, the enameled wire has not been improved in function but color by changing pigment added the coat.

 The current flowing over the enameled wire gives thermal, chemical, and magnetic actions, which can be proved by flowing the current over the enameled wire.

 Until now, the research on the enameled wire is focused at its thermal resistance
15 and insulation damage voltage but there is no effort for improving the functions of the enameled wire.

 Accordingly, the improvement of the basic function is required and the functional improvement will be of benefit to us.

 As described above, the conventional enameled wire has drawbacks in that there
20 is no solution for inhibiting the heat generation caused by the resistance of the wire itself, resulting in energy loss. Due to this problem, the thermal resistance of the varnish for enameled wire has been important.

Disclosure of the Invention

25 The present invention has been made in an effort to solve the above problem.

 It is an object of the present invention to provide a magnetoresistant enameled wire, a manufacturing method thereof, a magnetoresistant coil using the magnetoresistant

wire, and a manufacturing method of the magnetoresistant coil, that are capable of minimizing the energy loss as well as inhibiting temperature rise by reducing the resistance and load of the wire during the energy transfer thereon.

It is another object of the present invention to provide a magnetoresistant enameled wire, a manufacturing method thereof, a magnetoresistant coil using the magnetoresistant wire, and a manufacturing method of the magnetoresistant coil, that are capable of obtaining high exterior magnetic flux density

It is still another object of the present invention to provide a magnetoresistant enameled wire, a manufacturing method thereof, a magnetoresistant coil using the magnetoresistant wire, and a manufacturing method of the magnetoresistant coil, that are capable of preventing the isolation from being easily damaged.

It is still another object of the present invention to provide a magnetoresistant enameled wire, a manufacturing method thereof, a magnetoresistant coil using the magnetoresistant wire, and a manufacturing method of the magnetoresistant coil, that are capable of giving an effect similar to the anisotropic magnetoresistance even at low voltage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a conceptual view for illustrating directions of magnetic field when the high permeability substance is coated onto the conductor for obtaining an effect similar to the anisotropic magnetoresistance.

FIG. 2 is a conceptual view for illustrating a magnetic field formation in a typical enameled wire.

FIG. 3 is a conceptual view for illustrating a magnetic field formation in an enameled wire according to the present invention.

FIG. 4 is a sectional perspective view an essential part of an enameled wire according to the present invention.

Best Mode for Carrying Out the Invention

In order to achieve the above objects, the present invention provides a magnetoresistant enameled wire coated with an anisotropic magnetoresistant substance
5 or a substance having an equivalent effect thereto.

Here, the anisotropic magnetoresistant substance is a material which can be magnetized so as to form the magnetic fields in a different direction related to the direction of the electric current flowing through the conductive core wire composing of the enameled wire.

10 The method for manufacturing the magnetoresistant enameled wire according to the present invention comprises:

a) providing a conductive core wire; and

b) coating a varnish containing a material for obtaining the effect similar to a magnetoresistance effect on the outer surface of the conductive core wire, and softening.

15 The method for manufacturing the magnetoresistant enameled wire further comprises c) magnetizing the enameled wire manufacture by coating and softening the varnish containing the anisotropic magnetoresistant material.

Also, a method for manufacturing a magnetoresistant coil includes manufacturing a coil by winding the magnetoresistant enameled wire coated with the
20 material for obtaining the effect similar to the magnetoresistance effect.

The preferred embodiment of the present will be described hereinafter.

Firstly, the magnetoresistance effect and the magnetoresistant material will be described.

Thin film is fabricated by doping any substance on the flat board in the thickness
25 of one to several thousands atomic layers so as to obtain various characteristics other than in a lump of that material.

Furthermore, the thin film fabricated by layering a few different materials shows special characteristics. The thin film can be patterned with devices such as resistors, coils, condensers, transistors, etc. so as to be used for core parts of the CPU, memories, and hard disc, etc. In order to utilize the thin film, it is required to analyze the crystal
5 structure, crystal axis, and the accuracy of thickness.

The magnetoresistant material is one of the thin film substances. The magnetoresistance effect is a phenomenon in that the resistance of a material fluctuates according to the exterior magnetic force. Using this phenomenon, it is possible to measure changes of exterior magnetic field so as to be used for high capacity hard disc
10 drives.

It is not difficult to see the phrase "adoption of MR head" on the commercial hard disc drive advertisement. The magnetoresistant material is manufactured by alternately doping the magnetic substance and non-magnetic substance on the silicon substrate several times.

15 Samsung Electronics developed a silent high capacity hard disk drive (HDD) of 20.4Gb in November, 1999. This HDD was put on the market in three types of 10.2Gb, 15.3Gb, and 20.4Gb capacities in the name of spin point V10200 series. This series adopted the Giant Magnetoresistant (GMR) head which supports data transmission rate of 66MB per second. The head of this HDD was coated with the giant magnetoresistant
20 material having a large anisotropic magnetoresistance effect. In relation to the data storage, the Motorola Semiconductor Laboratory announced the development of a high speed magnetoresistance random access memory (MRAM) prototype operating at 3V on May 10, 2000 at www.edtn.com.

The magnetoresistance (MR) device uses the change of electric resistance
25 between the current electrodes when the electric current and magnetic field are applied to a thin semiconductor chip, which is divided into a semiconductor magnetoresistant device and giant magnetic substance-magnetoresistant device.

The semiconductor magnetoresistant device is structured by adhering shorted stripes on a long thin semiconductor in a direction perpendicular to the longitudinal direction of the semiconductor and installing a plurality of magnetoresistant devices in series such that the number of the magnetoresistant devices for increasing the resistance.

5 This device is utilized for non-contact variable resistor, potentiometer, fluxmeter, ammeter, displacement and oscillation pickup, multiplier, analog calculator, microwave wattmeter, revolution indicator, bank note identification sensor, etc. Ferromagnetic resistance device uses the negative magnetoresistance effect in which the resistance linearly decreases or anisotropic magnetoresistance effect in which the resistance

10 changes in anisotropic manner according to the angle between the magnetization direction and the current direction. To obtain the anisotropic magnetoresistance effect, the ferromagnetic resistance device should have a superior tolerance to the low magnetic field, is formed in bent line shape thin film for device miniaturization and high magnetization, and uses a Ni-Co alloy. The ferromagnetic resistance device

15 characteristically detects the direction of the magnetic field over the saturation magnetization (H_s), stabilizes the output level regardless of strength of the magnetic field, lowers temperature fluctuation of the output in comparison with the semiconductor, and can be used in high temperature. Also, it is possible to integrally arrange a plurality of sensors on the same substrate, enables to multi function, and maximize outputs in low

20 magnetic field and then immediately transit to saturation state.

This kind of ferromagnetic resistance device is typically used for the high density magnetic sensor, the high accuracy location sensor, the linear location sensor, the rotary encoder, the magnetic switch, the letter arranger of printer, etc.

To understand the basic principles of these various effects, it is required to study

25 from the announcement of the Hall effect. The British scientist, Stony, 10 century, asserted the electricity consists of indivisible particles and these are electrons, and an American, Millikan, measured the charge on an electron.

The Hall effect was discovered by Edwin Hall, a student of Johns Hopkins University in 1879. He found that when the electric current flows along a conductor in a direction perpendicular to an applied magnetic field, the conductor experiences a force acting normal to both directions.

5 The Hall effect is that when an electron moves along a direction perpendicular to an applied magnetic field, it experiences a force acting normal to both directions and moves in response to this force and the force effected by the internal electric field. The basic physical principle underlying the Hall effect is the Lorentz force. From this it is known the Hall voltage is proportional to the magnetic field. This is because it is
10 proportional to the density of the electric charge and this principle is commercially used and basic principle for the ordinary magnetoresistance.

The magnetoresistance (MR) is the effect in that the electric resistance of a material changes when the magnetic field is applied to the material and operates in several mechanisms.

15 Firstly, in case of using Hall effect when the magnetic field is applied to the non-magnetic substance or semiconductor material such as Au, the conduction electrons experience the Lorentz force such that the electrons draws circular orbit, resulting in generation of resistance. This is often called Ordinary Magnetoresistance (OMR) and has weak strength less than 1%.

20 Secondly, there is a magnetoresistance generated on the ferromagnetic material in addition to the Ordinary magnetoresistance. This is caused by spin-orbit coupling such that the magnetoresistance is supported by the easy axis of the ferromagnetic material and directions of the exterior magnetic field and electric current. This is called as anisotropic magnetoresistance (AMR).

25 The Permalloy shows a change about 2% and are used for typical MR sensor or magnetic reproducing head. In other words, this is called longitudinal effect or sound magnetoresistance.

Thirdly, when the conduction electron passes between the close magnetic layers the giant magnetoresistant (GMR) is generated caused by the spin dependent scattering according to the difference of the spin direction.

For further study, it is recommended to refer to Nam Hoe Huh et al. "Giant
5 magnetoresistant material: Research, Present Status, and Trends" in The Physics and
High tech" Vol. No. 11, 8, November 1999. The Nam Hoe Huh Ph. D is the chief of
the Giant Magnetoresistant Material Research Center of Korea Research Institute of
Standards and Science. This report says "When the magnetic field is applied to a
conductor, typically the resistance of the conductor increases because the flow of
10 electrons becomes slow. However, some materials show the effect in which the
resistance increases. Among them the materials having the characteristic of resistance
reduction over 1000% are called Colossal Magnetoresistant (CMR) materials. (omit
hereinafter)"

In view of utilization, these magnetic materials are focused on for the magnetic
15 core of the power supply of the industrial equipment such as the display monitor, color
television set, VCR, computer, facsimile, potential transformer, etc. and for the fields
associated with the magnetic recording media or reproducing head.

Additionally, the composite magnetic material is manufactured, by means of the
injection molding, transfer molding, extrusion molding, etc., as the molding material of
20 printed circuit board, semiconductor package material, molding material for winding
coil, cores for various coils, troy, core material for clamp filter, housing or cover material
of connector, coats of various cables, or optical source of various electric equipments for
improving the characteristics such as isolation, workability, anti corrosion, and high
frequency and voltage tolerance. However, there was no research for the resistance
25 reduction and conductivity of the conductor in relation with the substantial energy
transmission.

In the present invention, the enameled wire is manufactured by coating a wire with high permeability magnetic material for obtaining the magnetoresistance effect or the so as to form the interior an exterior magnetic fields, resulting in enameled wire having the magnetic resistance or similar characteristic.

5 Here, the magnetic resistance characteristic is the effect in that the conductivity is improved and the electric resistance decreases when the coated magnetic material is magnetized by the magnetic field generated by the electric current flowing on the conductive core wire in order for the conductive core wire to be in the magnetic field formed by the magnetic material.

10 As described above, similar to the changes of the electric resistance of the material in accordance with the magnetic field, there is an experiment for testing the variance of the resistance according to the magnetic field applied to the enameled wire.

In this experiment, an enameled wire having a diameter of 0.41mm and length of 234.6m is fitly wound around a cylindrical aluminum tube while its specific resistance
15 shows approximate 33.7Ω . In this state, if a composite oxide magnet draws to the wound coil and moves from side to side, its resistance fluctuates in the range of 11 ~ 86Ω .

Also, if a composite oxide magnet having much larger cross section draws to the coil and moves up and down, the range of the resistance variation increases.

20 However, when the permanent magnet is located around the coil without movement, the specific resistance of the enameled wire returns to the initial measurement value of 33.7Ω while the magnetic field of the permanent magnet is applied.

In this experiment, the magnetic material is coated onto the enameled wire for similar to the permanent magnet around the enameled wire. This experiment shows that
25 when the magnetic material is magnetized by the current flowing on the enameled wire, the specific resistance of the enameled wire changes by the magnetic field generated by the magnetic material.

From this experiment, it is proved that the effect similar to the magnetoresistance, especially the Tunnel Magnetoresistance (TMR) can be obtained.

The main focus on the magnetoresistance effect is to obtain large resistance variation even in weak magnetic. In the magnetoresistant research field, the Giant Magnetoresistance effect is discovered using the artificial magnetic lattice of the iron and nickel in 1988.

Separately, there has been research on the tunneling Giant magnetoresistance effect using the spin polarization. The tunneling magnetoresistance effect is based on the assumption that electrons tunneling from a non-magnetic layer are spin polarized and their polarization is given in terms of the spin-dependent density of states of the non-magnetic layer.

The magnetoresistance effect or the like according to the present invention will be described hereinafter in more detail.

That is, magnetic, non-magnetic and magnetic layers are sequentially layered to prepare a magnetoresistant material (Perovskite structure). When the magnetoresistant material is electricity-applied, magnetoresistance is created. Main conductors of enameled wires such as gold (Au), silver (Ag) and copper (Cu) are diamagnetic materials from a narrow view, but in fact paramagnetic materials from a broad view. The paramagnetic materials exhibit paramagnetism instead of diamagnetism in terms of their characteristics. Although the paramagnetic materials are metals, lines of magnetic force penetrate the metals. Accordingly, the paramagnetic materials have no ability capable of blocking the lines of magnetic force. By the fact that an enameled wire including a spiral of a paramagnetic material such as gold, silver, copper, aluminum, etc. can form a conductor, high magnetic permeability material powders are diluted in an insulating varnish for coating an enameled wire and a self-bonding insulating varnish and coated onto the varnishes to exhibit effects similar to anisotropic magnetoresistance. High magnetic permeability materials are magnetized in a first magnetic field created when the

enameled wire is electricity-applied. At this time, the enameled wire is positioned in a second magnetic field created by the high magnetic permeability material to make spins well flow in a predetermined direction, thereby reducing electric resistance.

The magnetoresistant coil of the present invention is manufactured by winding
5 the magnetoresistant enameled wire manufactured by coating the enameled wire with material showing the magnetoresistance effect or similar effect. The material having similar effect to anisotropic magnetoresistance can be coated onto the enameled wire in various manners.

In the coil manufactured using the enameled wire of the present invention, the
10 coated high permeability material is magnetized so as to form the magnetic fields simultaneously inside and outside the wire stronger than in the conventional coil. Particularly, since the conductor is located in the inside magnetic field, the electric resistance of the conductor decreases as in the anisotropic magnetoresistant or tunneling magnetoresistance effects.

15 Using this effect, the conductivity of the coil is enhanced so as to inhibit the temperature rise, resulting in minimization of the energy loss. Also, the magnetic field generated from the conductive core wire of the enameled wire while the electric current flows through the coil magnetizes the high permeability material such that the magnetic field created by the dependently magnetized high permeability material generates the
20 magnetic field greater than that formed inside and outside the enameled wire.

The formation of the magnetic field can be easily understood with reference to the drawings.

FIG. 1 is a conceptual view illustrating the direction of the magnetic field when the conductor is coated with the high permeability material. The arrow in FIG. 1 is the
25 direction of the magnetic field. Accordingly, when the high permeability material is fully coated onto the conductive core wire, the conductive core wire is located in the

magnetic field generated by the magnetized high permeability material so as to experience the effect similar to the anisotropic magnetoresistance.

To achieve the effect pursued by the present invention, the high permeability material can be magnetized and demagnetized by applying and releasing the electric
5 current therethrough and is used by mixing dispersing with the varnish. Even the high permeability material is magnetized, it is not matter if the material dispersal enough. However, if the powder is strongly magnetized so that the magnetoresistant materials are adhered to each other or to the agitator, while mixing with the varnish, like the permanent magnet, it is difficult to use the material.

10 The high permeability material should have a magnetic flux density greater than that of iron oxide. It is difficult to obtain the effect of the present invention with the iron oxide and the effect is weak even though it can be obtained, in the normal temperature.

To overcome this problem, it can be considered to increase the amount of the
15 material, however, the improvement of the effect is limited and it is difficult to mix and disperse with the varnish.

Compounds usable as the high magnetic permeability materials in the present invention are divided into the following three categories, and most of magnetically soft materials and low-loss oxide magnetic materials can be used.

20 i) magnetoresistant materials containing at least one metal selected from rare earth metals and transition metals, in particular high magnetic permeability magnetically soft alloys;

ii) magnetoresistant materials containing at least one metal selected from rare earth metals and transition metals, in particular high magnetic permeability magnetically
25 soft composite oxides; and

iii) magnetoresistant materials containing at least one metal selected from rare earth metals and transition metals, in particular high magnetic permeability magnetically soft composite nitrides.

A mixture of these compounds can be contained in an insulating varnish of the present invention.

In addition, magnetically hard materials, which are permanent magnet materials, can be used. Since the magnetically hard materials require a large amount of energy during magnetizing a material, there is a disadvantage that a large capacity of currents is required.

The magnetic materials are largely divided into ferromagnetic materials and paramagnetic materials. The ferromagnetic materials are sub-divided into magnetically soft materials and magnetically hard materials. The magnetically soft materials refer to high magnetic permeability materials which are magnetized in a weak magnetic field. The magnetically hard materials refer to high resistance magnetic materials capable of maintaining magnetic flux density to be constant against a magnetic field which reduces magnetic flux by a magnet. In a place where a current flows to form a high magnetic field, the magnetically hard materials can reduce resistance. However, it is preferred to select magnetically soft materials having a high magnetic permeability for common electrical and electronic uses.

Representative examples of the magnetically soft materials include metallic magnetically soft materials such as pure iron, Sendust, silicon steel, Permalloys, amorphous alloys, etc. The Permalloys include 45 Permalloy, 78 Permalloy and 81 Permalloy and the like according to their nickel contents. Further, the Permalloys Mo Permalloy, Cr Permalloy, Cu Permalloy, Si Permalloy, Ti Permalloy, Mu metal and the like containing other elements to improve the magnetic permeability.

The amorphous alloys include Co amorphous alloy, Fe amorphous alloy, Ni-Fe amorphous alloy and the like. The Ni-Fe amorphous alloy has a composition

comprising Ni-Fe as a base and at least one element selected from Mn, Cr, Co, Nb, V, Mo, Ta, W and Zr.

In addition, the magnetically soft materials include:

- (1) Ni-Fe-Mo-based 4% Permalloys,
- 5 (2) Ni-Cu-Zn-based magnetically soft ferrites,
- (3) Mn-Zn-based magnetically soft ferrites containing Fe_2O_3 , MnO, ZnO as main components and NiO, MgO, CuO, SiO_2 , CaO, V_2O_5 , TiO_2 , Nb_2O_5 , etc., as property-improving additives,
- (4) Ni-Zn-based magnetically soft ferrites,
- 10 (5) Mg-Mn-Zn-based magnetically soft ferrites,
- (6) Mg-Cu-Zn-based magnetically soft ferrites,
- (7) Fe-Ti-N-based magnetically soft ferrites,
- (8) Fe-Cr-based magnetically soft ferrites (minor components: C, N, Si, Mn, Ni, P, S, Cr, Al, Mo and Ti),
- 15 (9) Fe-Co-Ni-N-based magnetically soft ferrites,
- (10) Fe-Co-based magnetically soft ferrites,
- (11) Fe-Al-Si-based magnetically soft alloy powders,
- (12) Fe-Al-based magnetically soft alloy powders,
- (13) Fe-Si-B-Cu-Nb-based magnetically soft alloy powders,
- 20 (14) Fe-Br-B-Cu-based magnetically soft alloy powders,
- (15) Fe-B-M-N-R-based magnetically soft alloy powders (wherein M is an element selected from Hf, Zr and Nb, N is Cu element, R is at least one element selected from Ti, V, Ta, Cr, Mn, Mo, W, Au, Ag, Zn, Ga and Ge),
- (16) Fe-based magnetically soft alloy powders $((\text{Fe}_{1-x}\text{M}_x)_{100-a-b-c-d}\text{Si}_a\text{Al}_b\text{B}_c\text{K}_d)$
- 25 (wherein M is Co, Ni or a mixture thereof, K is at least one element selected from Nb, Mo, Zr, W, Ta, Hf, Ti, V, Cr, Mn, Y, Pd, Ru, Ge, C and P),

(17) Fe-based magnetically soft alloy powders (Fe is a base, either Co or Ni, and an additive is at least one element selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Mo and W) ,

(18) Fe-Zr-B-Ag-based magnetically soft alloy powders,

5 (19) Fe-Hf-based magnetically soft alloy powders,

(20) Fe-Si-based, Fe-Si-Al-based, Fe-Ni-based magnetically soft alloy powders,

(21) magnetically soft alloy powders composed of Fe-(at least one element selected from Ta, Hf, Zr, Nb, Mo, Al, Si, Ti, Cr and W)-(at least one element selected from C, N, O and B)-P,

10 (22) magnetically soft powders having a composition consisting of iron oxide (Fe_2O_3), nickel oxide (NiO), zinc oxide (ZnO), copper oxide (CuO) and bismuth oxide (Bi_2O_3),

(23) magnetically soft powders having a composition consisting of Fe-Co-(at least one element selected from Sm, Er, Tm, Yb and Ho as rare earth metals)-(at least one element selected from C, N, O and B, elements for microcrystallization),

15 (24) Mg-Zn-based, Mn-Al-based, Co-Pt-based, Cu-Ni-Co-based, Cu-Zn-based, Mn-based, Co-based, Li-based, Mg-based, Mn-based magnetically soft ferrite powders; and

(25) magnetically soft composite oxides containing one or more compounds
20 selected from Fe_2O_3 , Fe_3O_4 and CoFe_2O_4 as main components.

Since the magnetic materials of the present invention have a relatively low magnetic permeability, residual magnetic flux density (BR) and maximum energy product $(\text{BH})_{\text{max}}$, they are preferably used in the forms of alloys, oxides, nitrides or mixtures thereof. The term "magnetoresistant materials" used herein refers to the high
25 magnetic permeability materials and the magnetically soft materials, and the term "magnetically hard materials" refers to permanent magnet materials having a high coercive force.

The ferrites among the magnetically soft materials and the magnetically hard materials refer to composite oxides and prepared by mixing raw materials and calcining the mixture, or by other processes. The ferrites are not prepared by simply diluting iron oxides.

5 Examples of the ferrites include barium-iron-based composite oxides and strontium-iron-based composite oxides. These ferrites are prepared as follows.

 The main component, iron oxide (Fe_2O_3), is obtained by washing iron oxides generated during producing thin plates in ironworks with hydrochloric acid, and collecting iron oxide from the waste solution. Thereafter, the iron oxide and barium carbonate (BaCO_3) or strontium carbonate (SrCO_3) or the like are weighed, and then the
10 weighted compounds are mixed. The mixing step is carried out to contact raw materials each other to chemically react them. In the present invention, the mixing step is carried out in a ball mill for 5~20 hours. The mixture obtained thus is then plasticized. The plasticizing step is carried out by heating to $1,300^\circ\text{C}$ in a rotating furnace. The
15 plasticizing step is carried out to make the mixture a ferrite to some extent so as to facilitate contraction in the next calcining step.

 When the plasticized material is in the form of a hard lump, it is taken out from the furnace. The plasticized material is ground into powders having a particle size of 1micron using water and iron balls. The grinding step is carried out to enlarge the
20 surface area of the material, thereby improving reactivity or sinterability in next steps.

 The ground material is applied to a method for producing an isotropic composite oxide and a method for producing an anisotropic composite oxide. First, in the case of the isotropic ferrite, a binder or a lubricant is mixed with the ground material, and the resulting mixture is subjected to press molding to harden into a desired shape and size.

25 In contrast, in the case of the anisotropic ferrite, pressing is carried out in magnetic field to align the magnetic direction, and pressurizing and molding follow. The series of steps improves magnetization in next steps. Both the isotropic and

anisotropic ferrites are sintered in a furnace. At this time, these ferrites are hardened by heating them to 1,000°C over 25~26 hours. When the sintering is completed, the total volume is decreased compared to initial volume prior to sintering. Such a volume shrinkage is removed by sanding/polishing steps.

5 The magnetoresistant materials used in the present invention are classified into oxides containing no metal components, nitrides and compounds containing metal components. This classification is based on conductivity. The magnetoresistant materials are used in the form of a dispersion in a varnish. When a conductive magnetoresistant material containing metal components is used, the material is coated as
10 closely to a conductor as possible and then an insulating layer is preferably formed on a shell so as to prevent breakdown of insulation capacity. In particular, a space between a conductive core wire and the magnetoresistant material to be coated thereon is preferably formed as small as possible. The particle size of the magnetoresistant material is preferably small. Alternatively, if the magnetoresistant material containing metal
15 components is coated onto the outer surface of the insulating layer, it is difficult to maintain the insulation capacity of the enameled wire due to breakdown of the insulating varnish layer. The breakdown of the insulating varnish layer happens because an electricity flowing in a conductor tends to flow toward the parts coated with the metal components.

20 When the magnetoresistant material is coated onto the outer layer, a first layer or a second layer is formed to identify a sufficient insulation breakdown voltage and then the magnetoresistant material is coated.

 Oxide-based or nitride-based compounds having no conductivity, or magnetoresistant material of which the powder particles are insulated does not affect
25 their conductivity, and thus it is reasonable to say that they can be dispersed into everywhere of the insulation layer.

The magnetoresistant material is mixed with a varnish to prepare a magnetoresistant varnish. At this time, the magnetoresistant material is preferably present in an amount of 0.3~30% by weight based on the solid content. When the magnetoresistant material is present in an amount of less than 0.3 % by weight, it is
5 difficult to obtain sufficient magnetoresistance such as magneto motive force, coercive forces, magnetic flux density and magnetic permeability.

On the other hand, when the magnetoresistant material exceeds 0.3 % by weight, it cannot be dispersed into the varnish or the appearance of a magnetoresistant enameled wire to be manufactured is not smooth. In addition, agglomeration and expansion can be
10 caused. Furthermore, the intensity of magnetic field is not increased in proportional to the added amounts.

Hereinafter, a method for preparing a varnish containing the magnetoresistant material for coating an enameled wire will be explained.

In the present invention, the magnetoresistant material is mixed with a varnish,
15 and then the mixture is preferably coated onto the outer surface of a conductive core wire. The varnish is a common one for an enameled wire. Preferably, the magnetoresistant material of the present invention is contained in an insulating varnish or a self-bonding insulating varnish. The insulating varnish containing the magnetoresistant material of the present invention is coated onto the conductive core
20 wire to form an insulating varnish layer, and the self-bonding insulating varnish containing the magnetoresistant material of the present invention forms a magnetoresistant self-bonding insulating varnish layer.

The insulating varnish commonly forms an insulating varnish layer at an outer surface closest to the core wire and the insulating varnish layer plays a role as an
25 insulation layer. Also, the magnetoresistant self-bonding insulating varnish is coated onto the outer part of the insulation layer to form a self-bonding insulation layer, which and plays a role as a self-bonding layer and an insulation layer. If the magnetoresistant

material of the present invention is contained either in the insulating varnish layer formed at the outer surface of a conductive wire, or in the self-bonding insulating varnish layer, sufficient magnetoresistance effects can be obtained. Further, the magnetoresistant material can be contained both in the insulating varnish layer and in the self-bonding
5 insulating varnish layer.

Accordingly, the magnetoresistant varnish layer containing the magnetoresistant material is formed at the outer surface of the conductive core wire, which is a conductor of the enameled wire according to the present invention. If necessary, the magnetoresistant material can be contained in the self-bonding varnish layer formed at
10 the outer surface of the magnetoresistant varnish layer, or in a second or third insulating varnish layer. Of course, there is no problem in maintaining their insulation capacity.

The enameled wire and the coil of the present invention can be used at varying voltages ranging from high voltages to low low voltages.

As the insulating varnish containing the magnetoresistant material of the present
15 invention, common insulating varnishes for an enameled wire can be used. The insulating varnish containing the magnetoresistant material of the present invention is prepared by adding a dispersing agent and a magnetoresistant material to an insulating varnish, and stirring the mixture. The preferred dispersing agent is preferably at least one dispersing agent selected from the group consisting of general oil-based dispersing
20 agents, polyethylene polymeric protective colloid-based dispersing agents and higher fatty acid-based dispersing agents. The amount of the dispersing agent used is preferably within the range of 0.5~3.0 parts by weight, based on 100 parts of the insulation material containing the magnetoresistant material.

The common insulating varnish for an enameled wire includes:

- 25
- i) polyester varnishes for an enameled wire;
 - ii) polyurethane varnishes for an enameled wire;
 - iii) polyvinylformal varnishes for an enameled wire;

- iv) polyesterimide varnishes for an enameled wire;
- v) polyamideimide varnishes for an enameled wire;
- vi) polyimide varnishes for an enameled wire, and the like.

The above insulating varnishes are commonly used varnishes, and will be
5 explained below.

The polyester varnishes for an enameled wire of i) above are prepared in accordance with the following procedure. First, a polyester resin having a number average molecular weight of about 5,000 is obtained at high temperature on the basis of an esterification between a polyvalent acid and a polyvalent alcohol. Various
10 crosslinking agents, additives and solvents are mixed with the polyester resin to prepare the final polyester varnish for an enameled wire. The polyester varnishes for an enameled wire are mainly used in rotational motors, general and large transformers, etc. Index of heat resistance index of the polyester varnish for an enameled wire is B - F type (heat resistance temperature: 130~155°C).

15 The polyurethane varnishes for an enameled wire of ii) above comprise a polyisocyanate containing isocyanate groups (-NCO) and a polyester-based polyol containing hydroxyl groups (-OH) as main components. In practical applications, a blocked polyisocyanate is used to react the isocyanate groups with the hydroxyl groups by heating. The blocked polyisocyanate is stable in the form of a 1-liquid at room
20 temperature. The polyurethane varnishes for an enameled wire are mainly used in general transformers of household appliances, etc. Index of heat resistance of the polyurethane varnishes for an enameled wire is E-F type (heat resistance temperature: 120~155°C).

The polyvinylformal (PVE) varnishes for an enameled wire of iii) above are
25 prepared by adding epoxy, melamine and the like to a polyvinylformal resin among polyvinylacetal resins. Since the polyvinylformal (PVE) varnishes for an enameled wire have excellent wear resistance and coolant resistance, they are mainly used in

refrigerators, air-conditioners and motors for closed compressors requiring coolants. Further, incorporation of urethane groups to a basic formal copper wire enamel or other modifications are possible. Index of heat resistance of the polyvinylformal varnishes for an enameled wire is E-B type (heat resistance temperature: 5 120~130 °C).

The polyesterimide varnishes for an enameled wire of iv) above have improved thermal resistance by introducing imide groups having excellent thermal resistance stability into an existing polyester resin. The polyesterimide varnishes for an enameled wire are mainly used in devices requiring high thermal resistance in terms of reliability 10 related to life time of electrical and electronic devices. The polyesterimide varnishes for an enameled wire are mainly used in motors for electric tools, window brushes for automobiles, various motors, and HVT (High Voltage Transformer), etc. Index of heat resistance of the polyesterimide varnishes for an enameled wire is E-N type (heat resistance temperature: 155~200 °C).

15 The polyamideimide varnishes for an enameled wire of v) above are prepared by copolymerizing an aromatic amide and an imide. Since the structure is linear and consists of an aromatic macromolecule, mechanical, electrical and chemical durability are superior. The polyamideimide varnishes for an enameled wire are mainly prepared by reacting 4,4'-methylene diisocyanate (MDI) and trimellitic anhydride (TMA). The 20 polyamideimide varnishes for an enameled wire are mainly used in the field of electronic and electrical devices, shipbuilding and aircraft. Index of heat resistance of the polyamideimide varnishes for an enameled wire is H-N type (heat resistance temperature: 180~220 °C).

The polyimide varnishes for an enameled wire of vi) above have the most 25 thermal resistance. The polyester varnishes for an enameled wire are prepared in accordance with the following procedure. First, an aromatic polyvalent acid such as pyromellitic dianhydride (PMDA) and benzophenon dianhydride (BPDA) and an

aromatic polyvalent amine are reacted to obtain a polyamic acid in the liquid phase. Imide rings are formed by heating the polyamic acid to prepare the polyimide enameled wire. The polyimide varnishes for an enameled wire are mainly used in the field of aircraft and transformers for metropolitan power supply and defense industry devices, etc. Index of heat resistance of the polyimide varnishes for an enameled wire is C type (heat resistance temperature: 250°C or more).

The self-bonding insulating varnish containing the magnetoresistant material of the present invention is disposed at the outermost part of an enameled wire. After the enameled wire is wound, the wound enameled wire is bonded with a self-bonding varnish using heating, electricity applying or solvent-treatment to manufacture a self-bonding coil. At this time, as the self-bonding insulating varnish, common self-bonding insulating varnishes for general enameled wires can be used.

The self-bonding insulating varnish usable in the present invention includes:

- i) polyvinylbutyral-based self-bonding varnishes;
- ii) phenoxy-based self-bonding varnishes;
- iii) polyamide-based self-bonding varnishes;
- iv) epoxy-based self-bonding varnishes, and the like.

The polyvinylbutyral-based self-bonding varnishes of i) above are prepared by imparting self-bonding characteristics to a thermoplastic and adhesive polyvinylbutyral resin selected from polyvinylacetal resins. In particular, since the polyvinylbutyral resin is soluble in some solvents, bonding by a solvent spray is possible.

The phenoxy-based self-bonding varnishes of ii) above are prepared by using a thermoplastic phenoxy resin selected from epoxy resins. The phenoxy-based self-bonding varnishes are suitable in solvent elution, electricity applying manner, heating manner.

The polyamide-based self-bonding varnishes of iii) above can be widely used in coils of household appliances due to their superior adhesive strength, surface smoothness

and thermal resistance. As the basic resin, nylon-11, 12 and copolymers can be used. The polyamide-based self-bonding varnishes can be designed so as to minimize occurrence of surface adhesiveness between enameled wires produced by hydrogen bonds, which are formed due to the reaction with moisture. The polyamide-based self-bonding varnishes are mainly used in deflection yoke coils and special coils of high definition televisions, and suitable for electricity applying and heating manners.

The epoxy-based self-bonding varnishes of iv) above are excellent in terms of high solidification of low viscosity-high non-volatile components, adhesive strength, transformation post bonding and adhesion, and workability. Electricity applying manner is mainly applied.

The magnetoresistant enameled wire of the present invention is manufactured by coating the magnetoresistant varnish containing the magnetoresistant material onto the outer part of a conductive core wire, followed by softening to form a magnetoresistant varnish layer thereon.

Preferably, the magnetoresistant insulating varnish layer is formed by first applying an insulating varnish to the outer part of a conductor of a conductive core wire containing the magnetoresistant material, followed by softening. If necessary, a second or third insulating varnish is formed by coating a same or different resin optionally containing the magnetoresistant material, followed by softening.

Further, if necessary, the self-bonding magnetoresistant enameled wire is manufactured by coating a self-bonding varnish onto the outer part of the magnetoresistant varnish layer, followed by softening. Furthermore, the self-bonding magnetoresistant enameled wire is manufactured by coating and softening an insulation layer with no bonding characteristics containing no magnetoresistant material, followed by containing a magnetoresistant material in a self-bonding layer.

Furthermore, an insulation layer optionally containing a magnetoresistant material in the magnetoresistant varnish layer can be alternatively coated and

softened. To obtain a desired coat thickness of the insulation layer, coating and softening can be repeatedly carried out. The repeated coating and softening is because the repeatedly coated enameled wire is more excellent in terms of insulation capacity than an enameled wire formed at one time.

5 Coating of the magnetoresistant varnish, the self-bonding insulating varnish or the self-bonding magnetoresistant varnish onto a conductive core wire is performed by a common process such as a roll coating or impregnation. The softening process is preferably performed in a softening furnace. The temperature of the softening furnace is appropriately controlled depending on softening degree of the respective varnishes or
10 curing temperature, and preferably within the range of 400~700 °C.

 The present invention will be described in more detail with reference to the following Examples and Comparative Examples. However, these examples are given for the purpose of illustration and are not to be construed as limiting the scope of the invention.

15

[Example]

Comparative Example 1

(Preparation of general polyester-based insulating varnish)

20 28.11 parts by weight of dimethyl terephthalate (D.M.T), 6.69 parts by weight of ethylene glycol (E.G), 6.63 parts by weight of glycerin (purity: 95% by weight or more), 0.01 parts by weight of a metal catalyst of Tin-based metal salts and 17.28 parts by weight of meta-cresol (meta content: 55 parts by weight or more) were charged into a reactor, and then the resulting mixture was reacted at a temperature of
25 150~250 °C. When the softening point reached 85 ± 2 °C, the reaction was finished. 7.41 parts by weight of phenol, 18.58 parts by weight of xylene, 10.20 parts by weight of solvent-naphtha, 1.75 parts by weight of tetra-n-butyltitanate (T.B.T), 1.09

parts by weight of Zn-Octoate (zinc content: 8% by weight), and 2.25 parts by weight of polyisocyanate (-NCO content: 5% by weight) were sequentially added to the reactant, and diluted to prepare a polyester-based insulating varnish. The viscosity of the varnish thus prepared was 3 ± 0.5 poise at 25°C , and the solid content was $35 \pm 0.5\%$ by weight (after dried at 200°C for 2 hours).

(Manufacture of general polyester-based insulating varnish-coated enameled wire)

The general polyester-based insulating varnish thus prepared was coated onto a copper conductor wire (diameter: 1.0mm) by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C . The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C , respectively.

The thickness of an insulating varnish layer in the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 3 below.

Example 1

(Preparation of polyester-based magnetically soft varnish)

1.225 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main components, and 0.125 parts by weight of a polyethylene polymeric protective colloid-based dispersing agent were added to 100 parts by weight of the general polyester-based insulating varnish prepared in Comparative Example 1. The mixture was stirred and

dispersed to prepare a polyester-based varnish containing a magnetically soft material. The varnish thus prepared had a degree of softening degree of 4.

(Manufacture of polyester-based magnetically soft varnish-coated enameled
5 wire)

A magnetically soft material-type enameled wire was manufactured in the same manner as in Comparative Example 1, except that the polyester-based magnetically soft varnish was coated instead of the general polyester-based insulating varnish.

The thickness of the varnish layer of the enameled wire thus manufactured was measured
10 to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 3 below.

[Table 3]

Classification		Comp. Example 1	Example 1	Test method (KS C3006)	KS C3107 Specification
Enameled wire	insulating layer	general polyester- based insulating varnish layer	polyester-based magnetically soft varnish layer	-	-
	appearance	good	good	visual examination	Smooth surface
	insulating layer thickness (mm)	0.019	0.019	outside micrometer	0.015 mm or more
	No. of pinholes	0/3	0/3	5m, 12 volt/1min	3 or less
	adhesiveness	good	good	4 m/sec, sharply increased	No cracks
	wear resistance(g)	good	good	one-way type(g)	minimum : 360 or more average : 445 or more
	insulation breakdown voltage(KV)	7.29	3.22	load 350 g	2.80 or more
	softening resistance (°C)	295	290	Temperature-rising method, load 400 g	240 °C or more
	thermal shock resistance	0/3, good	0/3, good	180 °C, 60min.	No cracks
	solvent resistance	4H, good	4H, good	Xylene, 60 °C/30min.	No surface bubbles, expansion and cracks

Comparative Example 2

5

(Preparation of general polyvinylformal-based insulating varnish)

15.69 parts by weight of metameta-cresol (meta content: 55 parts by weight or more), 10.49 parts by weight of solvent-naphtha, 11.89 parts by weight of xylene, 38.60 parts by weight of a polyisocyanate (-NCO content 5 % by weight of), 3.33 parts by weight of a polyvinylbutyral resin (Vinylec-L, Chisso, Japan), 0.25 parts by weight of Zn-octoate (zinc content: 8% by weight), 15.35 parts by weight of a polyester polyol (-OH content: 4.5% by weight) were charged into a reactor, and then the resulting mixture was reacted at a temperature of 150~250°C to prepare a polyvinylformal-based insulating varnish. The viscosity of the varnish thus prepared was 3 ± 0.5 poise at 25°C, and the solid content was $35 \pm 0.5\%$ by weight (after dried at 200°C for 2 hours).

10

(Manufacture of general polyvinylformal-based insulating varnish-coated enameled wire)

The general polyvinylformal-based insulating varnish thus prepared was coated onto a copper conductor wire (diameter: 1mm) by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

20 The thickness of the varnish layer of the enameled wire thus manufactured was measured to be 0.017mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 4 below.

Example 2

25 (Preparation of polyvinylformal-based magnetically soft varnish)

1.10 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main

components, and 0.05 parts by weight of a fatty acid polyamide-based dispersing agent were added to 100 parts by weight of the general polyvinylformal-based insulating varnish prepared in Comparative Example 2. The mixture was stirred and dispersed to prepare a polyvinylformal-based varnish containing a magnetically soft material. The
5 varnish thus prepared had a degree of softening of 4.

(Manufacture of polyvinylformal-based magnetically soft varnish-coated enameled wire)

A magnetoresistant enameled wire was manufactured in the same manner as in
10 Comparative Example 2, except that the polyvinylformal-based magnetically soft varnish was coated instead of the general polyvinylformal-based insulating varnish.

The thickness of the magnetically soft varnish layer of the enameled wire thus manufactured was measured to be 0.017mm using outan outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in
15 Table 4 below.

[Table 4]

Classification		Comp. Example 2	Example 2	Test method (KS C3006)	KS C3107 Specification
Enam eled wire	insulating layer	General Polyvinylformal-based insulating varnish layer	Polyvinylformal- based magnetically soft varnish layer	-	-
	appearance	good	good	visual examination	smooth surface
	insulating layer thickness (mm)	0.017	0.017	outside micrometer	0.015 mm or more
	No. of pinholes	0/3	0/3	5m, 12 volt/1min	3 or less
	adhesiveness	good	good	4 m/sec, sharply increased	no cracks
	wear resistance (g)	good	good	one-way type(g)	minimum : 360 or more average : 445 or more
	insulation breakdown voltage (KV)	6.92	3.64	load 350 g	2.80 or more
	softening resistance (°C)	275	268	Temperature-rising method, load 400 g	240 °C or more
	thermal shock resistance	0/3, good	0/3, good	180 °C, 60min.	no cracks
	solvent resistance	4H, good	4H, good	Xylene, 60 °C /30min.	no surface bubbles, expansion and cracks

Comparative Example 3

- 5 (Preparation of general polyurethane-based insulating varnish)
- 40.00 parts by weight of meta-cresol (meta content: 55 parts by weight or more),
9.40 parts by weight of solvent-naphtha, 12.70 parts by weight of xylene, 16.00 parts by

weight of a polyisocyanate(-NCO content: 11% by weight), 9.20 parts by weight of a polyisocyanate (-NCO content: 12 % by weight), 0.80 parts by weight of a polyamide resin (Ultramid-1C, BASF, Germany), 0.40 parts by weight of Zn-octoate (zinc content: 8% by weight), 17.50 parts by weight of a polyester polyol (-OH content: 4.5% by weight) were charged into a reactor, and then the resulting mixture was reacted at a temperature of 150~250°C to prepare a polyurethane-based insulating varnish. The viscosity of the varnish thus prepared was 3 ± 0.5 poise at 25°C, and the solid content was $35 \pm 0.5\%$ by weight (after dried at 200°C for 2 hours).

10 (Manufacture of general polyurethane-based insulating varnish-coated enameled wire)

The general polyester-based insulating varnish thus prepared was coated onto a copper conductor wire (diameter: 1.0mm) by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 50 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

20 The thickness of an insulating varnish layer in the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 5 below.

Example 3

25 (Preparation of polyurethane-based magnetically soft varnish)

1.20 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main

components, and 0.15 parts by weight of a fatty acid amide-based dispersing agent were added to 100 parts by weight of the general polyurethane-based insulating varnish prepared in Comparative Example 3. The mixture was stirred and dispersed to prepare a polyurethane-based magnetically soft varnish. The varnish thus prepared had a degree of softening of 4.

(Manufacture of polyurethane-based magnetically soft varnish-coated enameled wire)

A magnetically soft enameled wire was manufactured in the same manner as in Comparative Example 3, except that the polyurethane-based magnetically soft varnish was coated instead of the general polyurethane-based insulating varnish.

The thickness of the varnish layer of the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 5 below.

[Table 5]

Classification		Comp. Example 3	Example 3	Test method (KS C3006)	KS C3107 Specification
Enamel ed wire	insulating layer	general polyurethane- based insulating varnish layer	polyurethane-based magnetically soft varnish layer	-	-
	appearance	good	good	visual examination	smooth surface
	insulating layer thickness (mm)	0.019	0.019	outside micrometer	0.015 mm or more
	No. of pinholes	0/3	0/3	5m, 12 volt/1min	3 or less
	adhesiveness	good	good	4 m/sec, sharply increased	no cracks
	wear resistance (g)	good	good	one-way type(g)	minimum : 360or more average : 445or more
	insulation breakdown voltage (KV)	6.89	4.20	load 350 g	2.80or more
	softening resistance (°C)	267	259	Temperature- rising method, load 400 g	240 °C or more
	thermal shock resistance	0/3, good	0/3, good	150 °C, 60 min.	no cracks
	solvent resistance	4H, good	4H, good	Xylene, 60 °C/30min.	no surface bubbles, expansion and cracks

5 Comparative Example 4

(Preparation of general polyesterimide-based insulating varnish)

47.00 parts by weight of xylenolic acid, 18.30 parts by weight of ethylene glycol, 25.30 parts by weight of diethylene glycol, 77.80 parts by weight of tris-hydroxyethylisocyanurate, 20.70 parts by weight of glycerin (purity: 95% by weight or more), 103.70 parts by weight of dimethylterephthalate, 0.24 parts by weight of Zn-acetate, 118.04 parts by weight of trimellitic anhydride, 81.70 parts by weight of diaminodiphenylmethane, 421.00 parts by weight of meta-cresol (meta content: 55 parts by weight or more), 140.00 parts by weight of solvent-naphtha, 15.50 parts by weight of a crysel titanate polymer, 7.76 parts by weight of a resol-type phenol resin and 3.88 parts by weight of polyisocyanate (-NCO content: 4.5 % by weight MDI-based blocking type) were charged into a reactor, and then the resulting mixture was reacted at a temperature of 150~250 °C to prepare a polyesterimide-based insulating varnish. The viscosity of the varnish thus prepared was 3 ± 0.5 poise at 25 °C, and the solid content was $35 \pm 0.5\%$ by weight (after dried at 200 °C for 2 hours).

(Manufacture of general polyesterimide-based insulating varnish-coated enameled wire)

The general polyesterimide-based insulating varnish thus prepared was coated onto a copper conductor wire (diameter: 1.0mm) by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

The thickness of an insulating varnish layer in the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 6 below.

Example 4

(Preparation of polyesterimide-based magnetically soft varnish)

1.20 parts by weight of an isotropic magnetoresistant material of a composite
oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main
components, and 0.07 parts by weight of a polyethylene polymeric protective colloid-
based dispersing agent were added to 100 parts by weight of the general polyesterimide-
based insulating varnish prepared in Comparative Example 4. The mixture was stirred
and dispersed to prepare a polyesterimide-based magnetically soft varnish. The varnish
thus prepared had a degree of softening of 4.

(Manufacture of polyesterimide-based magnetically soft varnish-coated
enameled wire)

A magnetoresistant enameled wire was manufactured in the same manner as in
Comparative Example 4, except that the polyesterimide-based magnetically soft varnish
was coated instead of the general polyesterimide-based insulating varnish.

The thickness of the varnish layer of the enameled wire thus manufactured was
measured to be 0.019mm using an outside micrometer. Other mechanical properties of
the enameled wire were measured. The results are shown in Table 6 below.

[Table 6]

Classification		Comp. Example 4	Example 4	Test method (KS C3006)	KS C3107 Specification
Enamelled wire	insulating layer	general polyester imide-based Insulating varnish layer	polyester imide-based magnetically soft varnish layer	-	-
	appearance	good	good	visual examination	smooth surface
	insulating layer thickness (mm)	0.019	0.019	outside micrometer	0.015 mm or more
	No. of pinholes	0/3	0/3	5m, 12 volt/1min	5 or less
	adhesiveness	good	good	4 m/sec, sharply increased	no cracks
	wear resistance(g)	good	good	one-way type(g)	minimum : 360 or more average : 445 or more
	insulation breakdown voltage(KV)	7.84	5.03	Load 350 g	2.80 or more
	softening resistance(°C)	323	338	Temperature-rising method, load 400 g	300 °C or more
	thermal shock resistance	0/3, good	0/3, good	220 °C, 60 min.	no cracks
	solvent resistance	4H, good	4H, good	Xylene, 60 °C/30min.	no surface bubbles, expansion and cracks

Comparative Example 5

5 (Preparation of general polyamideimide-based insulating varnish)

134.0 parts by weight of trimellitic anhydride), 175 parts by weight of 4,4-methylenediphenyl diisocyanate, 418.0 parts by weight of N-methylpyrrolidone) and 137.0 parts by weight of dimethylformamide were charged into a reactor, and then the resulting mixture was reacted at a temperature of 150~250°C to prepare a polyamideimide-based insulating varnish. The viscosity of the varnish thus prepared

was 3 ± 0.5 poise at 25°C , and the solid content was $35 \pm 0.5\%$ by weight (after dried at 200°C for 2 hours).

(Manufacture of general polyamideimide-based insulating varnish-coated
5 enameled wire)

The general polyamideimide-based insulating varnish thus prepared was coated onto a copper conductor wire (diameter: 1mm) by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at
10 460°C . The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C , respectively.

The thickness of the varnish layer of the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of
15 the enameled wire were measured. The results are shown in Table 7 below.

Example 5

(Preparation of polyamideimide-based magnetically soft varnish)

1.35 parts by weight of a magnetically soft material of a composite oxide
20 containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main components, and 0.05 parts by weight of a fatty acid amide-based dispersing agent were added to 100 parts by weight of the general polyamideimide-based insulating varnish prepared in Comparative Example 5. The mixture was stirred and dispersed to prepare a polyamideimide-based magnetically soft varnish. The varnish thus prepared had a
25 degree of softening of 4.

(Manufacture of polyamideimide-based magnetically soft varnish-coated enameled wire)

A magnetically soft enameled wire was manufactured in the same manner as in Comparative Example 5, except that the polyamideimide-based magnetically soft varnish was coated instead of the general polyamideimide-based insulating varnish.

The thickness of the magnetically soft varnish layer of the enameled wire thus manufactured was measured to be 0.019mm using an outside micrometer. Other mechanical properties of the enameled wire were measured. The results are shown in Table 7 below.

10 [Table 7]

Classification		Comp. Example 5	Example 5	Test method (KS C3006)	KS C3107 Specification
Enameled wire	insulating layer	General polyamide imide-based insulating varnish layer	polyamideimide-based magnetically soft varnish layer	-	-
	appearance	good	good	visual examination	smooth surface
	insulating layer thickness(mm)	0.019	0.019	outside micrometer	0.015 mm or more
	No. of pinholes	0/3	0/3	5m, 12 volt/1min	3 or less
	adhesiveness	good	good	4 m/sec, sharply increased	no cracks
	wear resistance(g)	good	good	one-way type(g)	minimum : 360or more average : 445or more
	insulation breakdown voltage(KV)	7.29	7.42	load 350 g	2.80or more

	softening resistance(°C)	358	364	Temperature- rising method, load 400 g	300 °C or more
	thermal shock resistance	0/3, good	0/3, good	220°C, 60 min.	no cracks
	solvent resistance	4H, good	4H, good	Xylene, 60 °C/30min.	no surface bubbles, expansion and cracks

Comparative Example 6

(Preparation of polyvinylbutyral-based self-bonding insulating varnish)

- 5 31.50 parts by weight of meta-cresol(meta content: 55 % by weight or more),
79.40 parts by weight of xylene, 31.00 parts by weight of dimethylformamide, 1.35 parts
by weight of a epoxy-phenol modified resin and a polyvinylbutyral resin (Monsanto,
Morbital B-30H) were reacted at a temperature of 150~250°C to prepare a
polyvinylbutyral-based self-bonding insulating varnish.

10

(Manufacture of enameled wire comprising general polyester-based insulating
varnish layer and polybutyral-based self-bonding insulating varnish layer)

- 15 The polybutyral-based self-bonding insulating varnish thus prepared was coated
onto the general polyester-based insulating varnish-coated enameled wire manufactured
in Comparative Example 1 by a roll coating manner, softened in a softening furnace, and
then dried in a drying furnace. The length of the softening furnace was 4M, and the
temperature of the softening furnace was maintained at 460°C. The flux in the softening
furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M,
and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and
20 540°C, respectively.

Example 6

(Manufacture of self-bonding magnetically soft enameled wire comprising polyester-based magnetically soft varnish layer and polyvinylbutyral-based self-bonding insulating varnish layer)

The polyvinylbutyral-based self-bonding insulating varnish prepared in Comparative Example 6 was coated onto the polyester-based magnetically soft varnish-coated enameled wire manufactured in Example 1 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

Example 7

(Preparation of polyvinylbutyral-based self-bonding magnetically soft varnish)

0.70 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main components, and 0.05 parts by weight of a polyethylene polymeric protective colloid-based dispersing agent were added to 100 parts by weight of the polyvinylbutyral-based self-bonding insulating varnish prepared in Comparative Example 6. The mixture was stirred and dispersed to prepare a polyvinylbutyral-based self-bonding magnetically soft varnish. The varnish thus prepared had a degree of softening of 4.

(Manufacture of self-bonding insulation enameled wire comprising general polyester-based insulating varnish layer and polyvinylbutyral-based self-bonding magnetically soft varnish layer)

The polyvinylbutyral-based self-bonding magnetically soft varnish thus prepared was coated onto the general polyester-based insulating varnish-coated enameled wire

manufactured in Comparative Example 1 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length
5 of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

Example 8

(Manufacture of self-bonding magnetically soft enameled wire comprising
10 polyester-based magnetically soft varnish layer and polyvinylbutyral-based self-bonding magnetically soft varnish layer)

The polyvinylbutyral-based self-bonding magnetically soft varnish prepared in Comparative Example 7 was coated onto the polyester-based magnetically soft varnish-coated enameled wire manufactured in Example 1 by a roll coating manner, softened in a
15 softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

20

[Table 8]

Classification		Comp. Example 6	Example 6	Example 7	Example 8
Enamel ed wire	insulating layer	general polyester-based insulating varnish	polyester-based magnetically soft varnish layer	general polyester-based insulating varnish	polyester-based magnetically soft varnish layer
	Self-bonding layer	Polyvinylbutyral-based self-bonding insulating varnish	Polyvinylbutyral-based self-bonding insulating varnish	Polyvinylbutyral-based self-bonding magnetically soft varnish	Polyvinylbutyral-based self-bonding magnetically soft varnish
	insulating layer thickness (mm)	0.013	0.019	0.019	0.019
	Self-bonding layer thickness(mm)	0.007	0.007	0.007	0.007
	No. of pinholes	0/3	0/3	0/3	0/3
	adhesiveness	good	good	good	good
	wear resistance(g)	good	good	good	good
	insulation breakdown voltage(KV)	8.3	7.9	8.7	7.6
	softening resistance(℃)	290	285	285	275
	thermal shock resistance	good	good	good	good
	solvent resistance	good	good	good	good

Comparative Example 7

- 5 (Preparation of polyvinylbutyral-based self-bonding insulating varnish)
- 12.30 parts by weight of meta-cresol (meta content: 55 % by weight or more),
 19.50 parts by weight of solvent-naphtha, 19.50 parts by weight of xylene, 20.00 parts by
 weight of a phenoxy resin (PKHH-3038), 8.18 parts by weight of phenol, 20.5 parts by

weight of butyl carbitol and 0.02 parts by weight of phthalic acid anhydride were reacted at a temperature of 150~250℃ to prepare a phenoxy-based self-bonding insulating varnish.

5 (Manufacture of enameled wire comprising general polyvinylformal-based insulating varnish layer and phenoxy-based self-bonding insulating varnish layer)

The phenoxy-based self-bonding insulating varnish thus prepared was coated onto the general polyvinylformal-based insulating varnish-coated enameled wire manufactured in Comparative Example 2 by a roll coating manner, softened in a
10 softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460℃. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460℃ and 540℃, respectively.

15

Example 9

(Manufacture of self-bonding magnetically soft enameled wire comprising polyvinylformal-based magnetically soft varnish layer and phenoxy-based self-bonding insulating varnish layer)

20 The phenoxy-based self-bonding insulating varnish prepared in Comparative Example 7 was coated onto the polyvinylformal-based magnetically soft varnish-coated enameled wire manufactured in Example 2 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at
25 460℃. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460℃ and 540℃, respectively.

Example 10

(Preparation of phenoxy-based self-bonding magnetically soft varnish)

1.00 parts by weight of a magnetically soft material of a composite oxide
5 containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main
components, and 0.12 parts by weight of a polyethylene polymeric protective colloid-
based dispersing agent were added to 100 parts by weight of the phenoxy-based self-
bonding insulating varnish prepared in Comparative Example 7. The mixture was
stirred and dispersed to prepare a phenoxy-based self-bonding magnetically soft
10 varnish. The varnish thus prepared had a degree of softening of 4.

(Manufacture of self-bonding insulation enameled wire comprising general
polyvinylformal-based insulating varnish layer and phenoxy-based self-bonding
magnetoresistant varnish layer)

15 The phenoxy-based self-bonding magnetically hard varnish thus prepared was
coated onto the general polyvinylformal-based insulating varnish-coated enameled wire
manufactured in Comparative Example 2 by a roll coating manner, softened in a
softening furnace, and then dried in a drying furnace. The length of the softening
furnace was 4M, and the temperature of the softening furnace was maintained at
20 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length
of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying
furnace were maintained at 460 °C and 540 °C, respectively.

Example 11

25 (Manufacture of self-bonding magnetically soft enameled wire comprising
polyvinylformal-based magnetically soft varnish layer and phenoxy-based self-bonding
magnetically soft varnish layer)

The phenoxy-based self-bonding magnetically soft varnish prepared in Example 10 was coated onto the polyvinylformal-based magnetically soft varnish-coated enameled wire manufactured in Example 2 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

[Table 9]

Classification		Comp. Example 7	Example 9	Example 10	Example 11
Enamel ed wire	insulating layer	general Polyvinylformal- based insulating varnish	Polyvinylformal- based magnetically soft varnish layer	general Polyvinylformal- based insulating varnish	Polyvinylformal- based magnetically soft varnish layer
	Self-bonding layer	phenoxy-based self-bonding insulating varnish	phenoxy-based self- bonding insulating varnish	phenoxy-based self- bonding magnetically soft varnish	phenoxy-based self-bonding magnetically soft varnish
	insulating layer thickness(mm)	0.013	0.013	0.013	0.013
	Self-bonding layer thickness(mm)	0.007	0.007	0.007	0.007
	No. of pinholes	0/3	0/3	0/3	0/3
	adhesiveness	good	good	good	good
	wear resistance(g)	good	good	good	good
	insulation breakdown voltage(KV)	7.5	7.2	6.8	7.4
	softening resistance(°C)	270	260	265	267
	thermal shock resistance	good	good	good	good
	solvent resistance	good	good	good	good

Comparative Example 8

5 (Preparation of polyamide-based self-bonding insulating varnish)

120.0 parts by weight of meta-cresol (meta content: 55 % by weight or more),
 1.3 parts by weight of solvent-naphtha, 126.0 parts by weight of xylene, 8.3 parts by
 weight of phenol, 0.75 parts by weight of an alkylphenol resin, 0.9 parts by weight of

polyisocyanate (-NCO content: 4.5 % by weight, MDI-based blocking type), 0.6 parts by weight of zinc octoate (zinc content: 8% by weight) and 60.0 parts by weight of a polyamide copolymer (Nylon 11-based) were reacted at a temperature of 150~250 °C to prepare a phenoxy-based self-bonding insulating varnish.

5

(Manufacture of enameled wire comprising general polyamideimide-based insulating varnish layer and polyamide-based self-bonding insulating varnish layer)

The polyamide-based self-bonding insulating varnish thus prepared was coated onto the general polyamideimide-based insulating varnish-coated enameled wire manufactured in Comparative Example 5 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

10
15

Example 12

(Manufacture of self-bonding magnetically soft enameled wire comprising polyamideimide-based magnetically soft varnish layer and polyamide-based self-bonding insulating varnish layer)

20

The polyamide-based self-bonding insulating varnish prepared in Comparative Example 8 was coated onto the polyamideimide-based magnetically soft varnish-coated enameled wire manufactured in Example 5 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length

25

of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

Example 13

5 (Preparation of polyamide-based self-bonding magnetically soft varnish)

1.30 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main components, and 0.05 parts by weight of a fatty acid amide-based dispersing agent were added to 100 parts by weight of the polyamide-based self-bonding insulating varnish prepared in Comparative Example 8. The mixture was stirred and dispersed to prepare a polyamide-based self-bonding magnetically soft varnish. The varnish thus prepared had a degree of softening of 4.

15 (Manufacture of self-bonding insulation enameled wire comprising general polyamideimide-based insulating varnish layer and polyamide-based self-bonding magnetically soft varnish layer)

The polyamide-based self-bonding magnetically soft varnish thus prepared was coated onto the general polyamideimide-based insulating varnish-coated enameled wire manufactured in Comparative Example 5 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

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Example 14

(Manufacture of self-bonding insulation enameled wire comprising polyamideimide-based magnetically soft varnish layer and polyamide-based self-bonding magnetically soft varnish layer)

The polyamide-based self-bonding magnetically soft varnish prepared in
5 Example 13 was coated onto the general polyamideimide-based magnetically soft
varnish-coated enameled wire manufactured in Example 5 by a roll coating manner,
softened in a softening furnace, and then dried in a drying furnace. The length of the
softening furnace was 4M, and the temperature of the softening furnace was maintained
at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The
10 length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying
furnace were maintained at 460°C and 540°C, respectively.

[Table 10]

Classification		Comp. Example 8	Example 12	Example 13	Example 14
Enameled wire	insulating layer	general Polyamideimide-based insulating varnish	Polyamideimide-based magnetically soft varnish layer	general Polyamideimide-based insulating varnish	Polyamideimide-based magnetically soft varnish layer
	Self-bonding layer	Polyamide-based self-bonding insulating varnish	Polyamide-based self-bonding insulating varnish	Polyamide-based self-bonding magnetically soft varnish	Polyamide-based self-bonding magnetically soft varnish
	insulating layer thickness(m m)	0.013	0.013	0.013	0.013
	Self-bonding layer thickness(m m)	0.007	0.007	0.007	0.007
	No. of pinholes	0/3	0/3	0/3	0/3
	adhesiveness	good	good	good	good
	wear resistance(g)	good	good	good	good
	insulation breakdown voltage(KV)	8.5	9.1	8.3	8.7
	softening resistance (°C)	352	347	349	340
	thermal shock resistance	good	good	good	good
	solvent resistance	good	good	good	good

Comparative Example 9

(Preparation of epoxy-based self-bonding insulating varnish)

62.0 parts by weight of an epoxy resin (epoxy equivalent weight: 186), 9.16 parts by weight of hydroquinone, 1.53 parts by weight of tri-n-butylamine (reagent grade), 9.16 parts by weight of resorcin and 186.7 parts by weight of methyl carbato were reacted
5 at a temperature of 150~250°C to prepare an epoxy-based self-bonding insulating varnish.

(Manufacture of enameled wire comprising general polyurethane-based insulating varnish layer and enameled wire-based self-bonding insulating varnish layer)

The epoxy-based self-bonding insulating varnish thus prepared was coated onto
10 the general polyurethane-based insulating varnish-coated enameled wire manufactured in Comparative Example 3 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M,
15 and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and 540°C, respectively.

Example 15

(Manufacture of self-bonding magnetically soft enameled wire comprising
20 general polyurethane-based magnetically soft varnish layer and epoxy-based self-bonding insulating varnish layer)

The epoxy-based self-bonding insulating varnish prepared in Comparative Example 9 was coated onto the polyurethane-based magnetoresistant varnish-coated enameled wire manufactured in Example 3 by a roll coating manner, softened in a
25 softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460°C. The flux in the softening furnace and drying furnace was 35 m/min. The length

of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

Example 16

5 (Preparation of epoxy-based self-bonding magnetically soft varnish)

1.20 parts by weight of a magnetically soft material of a composite oxide containing about 63% of FeO, about 23% of FeO, about 9% of CoFeO as main components, and 0.15 parts by weight of a polyethylene polymeric protective colloid-based dispersing agent were added to 100 parts by weight of the epoxy-based self-bonding insulating varnish prepared in Comparative Example 9. The mixture was stirred and dispersed to prepare an epoxy-based self-bonding magnetically soft varnish. The varnish thus prepared had a degree of softening of 4.

15 (Manufacture of self-bonding insulation enameled wire comprising general polyurethane-based insulating varnish layer and epoxy-based self-bonding magnetically soft varnish layer)

The epoxy-based self-bonding magnetically soft varnish thus prepared was coated onto the general polyurethane-based insulating varnish-coated enameled wire manufactured in Comparative Example 3 by a roll coating manner, softened in a softening furnace, and then dried in a drying furnace. The length of the softening furnace was 4M, and the temperature of the softening furnace was maintained at 460 °C. The flux in the softening furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M, and the inlet and outlet temperatures of the drying furnace were maintained at 460 °C and 540 °C, respectively.

25

Example 17

(Manufacture of self-bonding insulation enameled wire comprising polyurethane-based magnetically soft varnish layer and epoxy-based self-bonding magnetically soft varnish layer)

The epoxy-based self-bonding magnetically soft varnish prepared in Example 16
5 was coated onto the polyurethane-based insulating varnish-coated enameled wire
manufactured in Example 3 by a roll coating manner, softened in a softening furnace, and
then dried in a drying furnace. The length of the softening furnace was 4M, and the
temperature of the softening furnace was maintained at 460°C. The flux in the softening
furnace and drying furnace was 35 m/min. The length of the drying furnace was 3.4M,
10 and the inlet and outlet temperatures of the drying furnace were maintained at 460°C and
540°C, respectively.

[Table 11]

Classification		Comp. Example 9	Example 15	Comp. Example 16	Example 17
Enamelled wire	insulating layer	general polyurethane-based insulating varnish	polyurethane-based magnetically soft varnish layer	general polyurethane-based insulating varnish	polyurethane-based magnetically soft varnish layer
	Self-bonding layer	Epoxy-based self-bonding insulating varnish	Epoxy-based self-bonding insulating varnish	Epoxy-based self-bonding magnetically soft varnish	Epoxy-based self-bonding magnetically soft varnish
	insulating layer thickness(mm)	0.013	0.013	0.013	0.013
	Self-bonding layer thickness(mm)	0.007	0.007	0.007	0.007
	No. of pinholes	0/3	0/3	0/3	0/3
	adhesiveness	good	good	good	good
	wear resistance(g)	good	good	good	good
	insulation breakdown voltage(KV)	7.1	6.9	7.6	7.4
	softening resistance(°C)	269	265	270	275
	thermal shock resistance	good	good	good	good
	solvent resistance	good	good	good	good

Comparative Example 10

- 5 In order to identify the effects of the present invention, a small machine was fabricated. The small machine is a motor fabricated by forming polyester insulation layer as a second layer on 2kg of the single-coated enameled wire manufactured in

Comparative Example 1, and can be rotated in 2,800rpm at a rated voltage of 24V and a rated current of 1A.

The motor was fabricated in the same conditions as conventional processes, except that a rotor was wound with the enameled wire and impregnation-fixed.

5 The motor was fabricated by Omega Co, Ltd., Samjeong-Dong, Ojeong-Gu, Bucheon-City, Kyunggi-Province, Korea.

In order to indirectly evaluate how long the motor can be operated with the same energy due to resistance drop of magnetism and how much outer temperature can be lowered when operated at a rated voltage, revolutions per minute, total rotation time, and
10 outer temperature of the motor were measured. The results are shown in Table 12 below.

Example 18

2 motors of the same type were fabricated using the enameled wire manufactured in Example 1. The test results of these motors are shown in Table 12 below.

15

Comparative Example 11

An insulation layer was formed on a copper wire (diameter: 0.4mm) as a first layer using the polyester varnish for a enameled wire, and then a second layer was formed thereon in the thickness of 0.007mm using the same varnish to manufacture an
20 enameled wire. The mechanical properties of the enameled wire are shown in Table 13 below.

Example 20

(Preparation of polyester-based magnetoresistant varnish)

25 1.225 parts by weight of an oxide-based high magnetic permeability material containing Fe₂O₃, Fe₃O₄ and CoFe₂O₄ as main components and 0.125 parts by weight of a polyethylene polymeric protective colloid-based dispersing agent were added to 100

parts by weight of the polyester-based insulating varnish prepared in Comparative Example 1. The mixture was sufficiently wetted in a varnish liquid using a roll mill, and then stirred and dispersed to prepare a polyester-based magnetoresistant varnish.

5 (Manufacture of polyester-based magnetoresistant enameled wire)

The polyester-based magnetoresistant varnish thus prepared was applied to the first layer formed in Comparative Example 11 to form an enameled wire (thickness: 0.007mm). Other mechanical properties of the enameled wire are measured. The results are shown in Table 13 below.

10

[Table 13]

Classification		Comp. Example 11	Example 20
Enameled wire	First layer	polyester-based Insulating varnish	polyester-based Insulating varnish
	Second layer	polyester-based Insulating varnish	polyester-based magnetoresistant Insulating varnish
	First layer thickness(mm)	0.013	0.013
	Second layer thickness(mm)	0.007	0.007
	No. of pinholes	0/3	0/3
	adhesiveness	good	good
	wear resistance(g)	good	good
	insulation breakdown voltage(KV)	7.1	6.9
	softening resistance(°C)	269	265
	thermal shock resistance	good	good
	solvent resistance	good	good

Comparative Example 12

In order to identify the effects of the high magnetic permeability magnetically soft materials according to the present invention as magnetoresistant materials, a small machine was fabricated. The small machine is a direct current motor fabricated by forming 2kg of the enameled wire manufactured in Comparative Example 11 on a rotor, and can be rotated in 1,750rpm at a rated voltage of 90V and a rated current of 1A.

The motor was fabricated in the same conditions as conventional processes, except that a rotor was wound with the enameled wire and impregnation-fixed.

In order to indirectly evaluate how long the motor can be operated with the same energy due to resistance drop of magnetism and how much outer temperature can be lowered when operated at a rated voltage, revolutions per minute, total rotation time, and outer temperature of the motor were measured. The results are shown in Table 14 below.

Example 21

A motor of the same type was fabricated using the enameled wire manufactured in Example 20 in accordance with the same manner as in Comparative Example 12. The test results of the motor are shown in Table 14 below.

[Table 14]

Voltage	Item	Comp. Example 10	Example 18	Remarks	
90V direct current power	Outer temperature at initial operation	26.5℃	26.5℃	0	
	Outer temperature 12 hours after operation	42.3℃	34.0℃	8.3℃ (-20.80%)	
6 V dry cell	Total operational time		67:15:00	82:45:00	15:30:00
	Revolutions per time and rotation stop time	Initial	96 rpm	96 rpm	-
		1:00:00	96 rpm	102 rpm	-
		3:00:00	82 rpm	91 rpm	-
		5:00:00	79 rpm	88 rpm	-

		11:00:00	77 rpm	85 rpm	-
		16:00:00	70 rpm	80 rpm	-
		24:00:00	64 rpm	74 rpm	-
		48:00:00	47 rpm	59 rpm	-
		60:00:00	19 rpm	41 rpm	-
		67:15:00	0 rpm	37 rpm	-
		68:00:00	0 rpm	36 rpm	-
		82:45:00	0 rpm	0 rpm	-

From the experiment, the direct current motor fabricated by stirring and dispersing the high magnetic permeability magnetically soft materials as magnetoresistant materials in the varnishes for enameled wire, and coating the dispersion, had significant differences, compared to common motors, in terms of total rotation time, heating value, outer temperature.

Example 22

In order to more exactly examine the effects shown in Table 14, the motor fabricated in Comparative Example 12 was face to face with the motor fabricated in Example 21, the two motors were fixed using a flexible rubber band and a tape. During slowly raising rated voltage to 90V, the voltages values were measured. The results are shown in Table 15.

[Table 15]

Classification	Comp. Example12	Classification	Example 21
Input Volt	90.0	Detection Volt	87.1
Detection Volt	82.3	Input Volt	90.0

Example 23

In order to more exactly examine the effects shown in Table 15, the motors fabricated in Comparative Example 12 and Example 21 were face to face with another

motor, their rotors were fixed using a flexible rubber band and a tape. During slowly raising rated voltage to 90V, the voltages values were measured. The results are shown in Table 15.

5 [Table 16]

Classification	Comp. Example12	Example21
Minimum detection Volt	82.3	85.3
Maximum detection Volt	83.1	86.1

From the results, it can be seen that inner resistance and various losses were improved. Also, it can be seen that noises were considerably reduced during inversely rotating, and noises were reduce to some extents during normally rotating.

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Example 24

In order to examine the effects of induction motors fabricated using the enameled wires according to the present invention, comparative tests were carried out using enameled wires manufactured by the aid of Motor design department, Hyundai

15 heavy industries, Co. Ltd. The results are shown in Table 17 below.

[Table 17]

Classification	Unit	General induction motor (0.45) A	induction motor of the present invention (0.40) B	B-A	A-B/A(%)
enameled wire	H	Polyester 0.45	Example 20		
Output	Hp	0.536	0.536		
Efficiency	%	68.29	69.12	0.83	1.22%
Power factor	%	68.47	68.25	-0.22	-0.32%
Rated current	A	1.116	1.107	-0.01	-0.81%
No-load current	A	0.871	0.875	0.00	0.46%

Revolutions	Rpm	1,707	1,706	1.00	-0.06%
First copper loss	W	87.93	87.61	-0.32	-0.36%
Second copper loss	W	23.10	23.21	0.11	0.48%
Iron loss	W	51.62	44.81	-6.81	-13.19%
Mechanical loss	W	2.98	3.83	0.85	28.42%
Drift load loss	W	51.90	44.47	-7.44	-14.33%
Total loss	W	217.54	203.93	-13.61	-6.25%
Wire resistance	Ω	40.16	40.13	-0.03	-0.07%

From the tests, it can be seen that 0.40mm long magnetoresistant enameled wires of the present invention had less wire wound resistance than 0.45mm long general polyester enameled wires. Further, it was found that the enameled wires of the present invention had greatly reduced losses such as iron loss and drift load loss by an exterior magnetic field, compared to conventional enameled wires.

In accordance with the present invention, the magnetoresistant enameled wire comprising the magnetoresistant varnish layer containing high magnetic permeability magnetically soft materials as a magnetoresistant material considerably reduces energy loss due to resistance and load of a conductor, and a coil having strong magnetic flux density can be manufactured.

That is, the magnetoresistant enameled wire of the present invention has efficiency capable of improving current flow.

The improvement in current flow is due to a loss in conductor resistance, which inhibits temperature rise of a conductor and promotes current flow.

In accordance with the present invention, energy loss resulting from a load due to an overcurrent is minimized. The improvement in current flow minimizes energy loss even at room temperature without falling to superconducting temperature.

The magnetoresistant enameled wire of the present invention can be applied to coils used in machines using induction current, such as direct current motors, alternative

current motors, motors, generators, transformers, etc., and to machines requiring overheat prevention.

The coil manufactured by the magnetoresistant enameled wire of the present invention can have magnetically resistance at room temperature. When applied to power
5 lines, power loss due to self-resistance and load of transmission and distribution cables can be reduced. The resistance loss contributes to extending shortened life span of power lines resulting from degradation acceleration due to operational conditions.